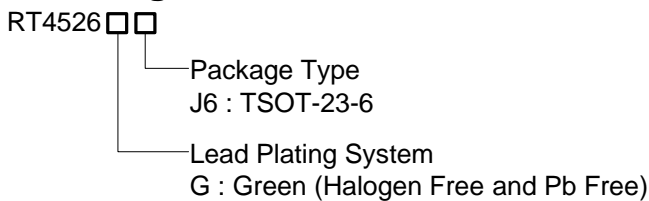# Small Package, High Performance, Asynchronous Boost LED Driver

General Description

The RT4526 is a high frequency, asynchronous boost converter. This converter can support White LEDs for backlighting and OLED power application, and the internal soft start function can reduce the inrush current. The device operates with 1MHz fixed switching frequency to allow small external components and to simplify possible EMI problems. For the protection, the RT4526 provides 30V OVP to allow inexpensive and small-output capacitors with lower voltage rating. The LED current is initially set with the external sense resistor R_{SET}. The RT4526 is available in the tiny package type TSOT-23-6 package to provide the best solution for PCB space saving and total BOM cost.

Ordering Information

RT4526☐☐

```
         Package Type
         J6 : TSOT-23-6

         Lead Plating System
         G : Green (Halogen Free and Pb Free)
```

Note :

Richtek products are :

 ‣ RoHS compliant and compatible with the current require-ments of IPC/JEDEC J-STD-020.

 ‣ Suitable for use in SnPb or Pb-free soldering processes.

Marking Information

For marking information, contact our sales representative directly or through a Richtek distributor located in your area.

Features

- V_{IN} Operating Range : 2.5V to 5.5V
- Internal Power N-MOSFET Switch
- Wide Range for PWM Dimming (100Hz to 200kHz)
- 1MHz Switching Frequency
- Minimize the External Component Count
- Internal Soft Start
- Internal Compensation
- Under Voltage Protection
- Over Voltage Protection
- Over Temperature Protection
- Small TSOT-23-6 Package
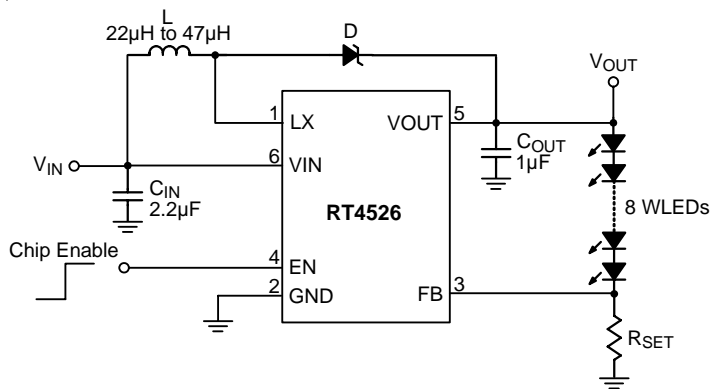- RoHS Compliant and Halogen Free

Applications

- Cellular Phones
- Digital Cameras
- PDAs and Smart Phones and MP3 and OLED
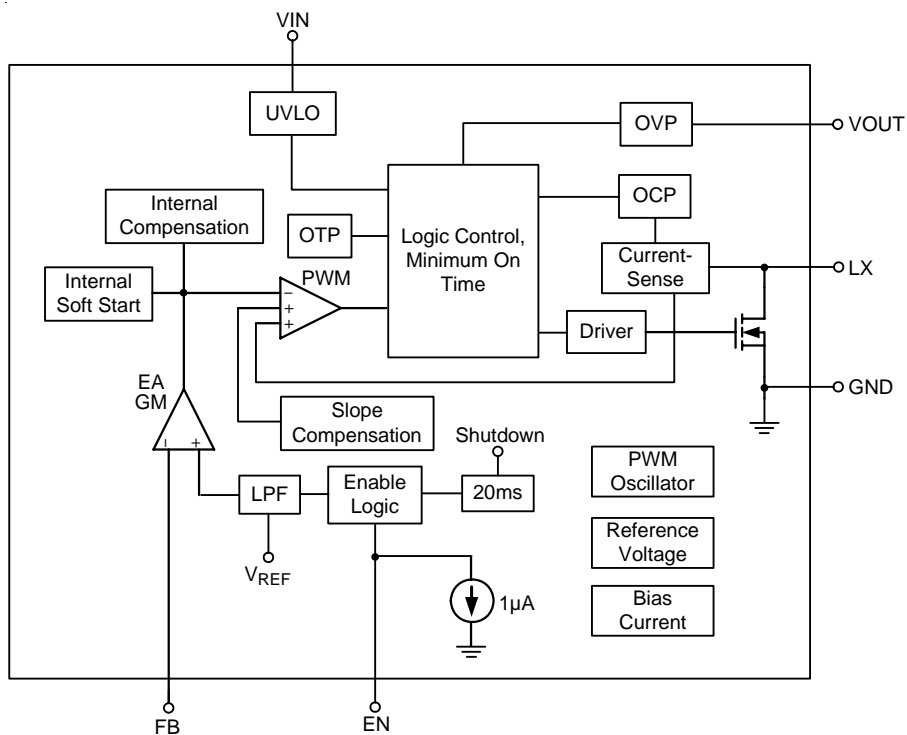- Portable Instruments

Pin Configurations

(TOP VIEW)

```
        VIN VOUT EN
         6    5    4

         1    2    3
        LX  GND  FB
```

TSOT-23-6
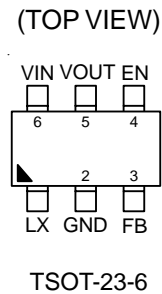
Typical Application Circuit

Functional Pin Description

Pin No.	Pin Name	Pin Function
1	LX	Switching.
2	GND	Ground.
3	FB	Feedback. Put a resistor to GND to set the current.
4	EN	Chip Enable (Active High).
5	VOUT	Output Voltage.
6	VIN	Input Supply.

Function Block Diagram

Absolute Maximum Ratings   (Note 1)

- Supply Input Voltage, V_{IN} --- −0.3V to 6V
- Switching Pin, LX -- −0.3V to 50V
- VOUT -- −0.3V to 46V
- Other Pins --- −0.3V to 6V
- Power Dissipation, P_D @ T_A = 25°C
  - TSOT-23-6 -- 0.392W
- Package Thermal Resistance   (Note 2)
  - TSOT-23-6, $θ_{JA}$ -- 255°C/W
- Lead Temperature (Soldering, 10 sec.) --- 260°C
- Junction Temperature -- 150°C
- Storage Temperature Range --- −65°C to 150°C

Recommended Operating Conditions   (Note 3)

- Junction Temperature Range -- −40°C to 125°C
- Ambient Temperature Range --- −40°C to 85°C

Electrical Characteristics

(V_{IN} = 3.7V, C_{IN} = 2.2µF, C_{OUT} = 1µF, I_{OUT} = 20mA, L = 22µH, T_A = 25°C, unless otherwise specified)

| Parameter		Symbol	Conditions	Min	Typ	Max	Unit
Input Voltage		V_{IN}		2.5	--	5.5	V
Under Voltage Lockout		V_{UVLO}		2	2.2	2.45	V
UVLO Hysteresis				--	0.1	--	V
Quiescent Current		I_Q	FB = 1.5V, No Switching	--	400	600	µA
Supply Current		I_{IN}	FB = 0V, Switching	--	1	2	mA
Shutdown Current		I_{SHDN}	V_{EN} < 0.4V	--	1	4	µA
Line Regulation			V_{IN} = 3 to 4.3V	--	1	--	%
Load Regulation			1mA to 20mA	--	1	--	%
Operation Frequency		f_{OSC}		0.75	1	1.25	MHz
Maximum Duty Cycle				90	92	--	%
Clock Rate				0.1	--	200	kHz
Feedback Reference Voltage		V_{REF}		285	300	315	mV
On Resistance		$R_{DS(ON)}$		--	0.7	1.2	Ω
EN Threshold	Logic-High Voltage	V_{IH}		1.4	--	--	V
	Logic-Low Voltage	V_{IL}		--	--	0.5	
EN Sink Current		I_{IH}		--	1	--	µA
EN Hysteresis				--	0.1	--	V
Over-Voltage Threshold		V_{OVP}		30	---	---	V
Over-Current Threshold		I_{OCP}		1	1.2	--	A
OTP		T_{OTP}		--	160	--	°C
OTP Hysteresis				--	30	--	°C
Shutdown Delay		T_{SHDN}		--	20	--	ms

Note 1. Stresses listed as the above "Absolute Maximum Ratings" may cause permanent damage to the device. These are for stress ratings. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

Note 2. θ_{JA} is measured in the natural convection at $T_A = 25°C$ on a low effective single layer thermal conductivity test board of JEDEC 51-3 thermal measurement standard. The case point of θ_{JC} is on the expose pad for the WDFN package.

Note 3. The device is not guaranteed to function outside its operating conditions.

Typical Operating Characteristics

Efficiency vs. Output Current
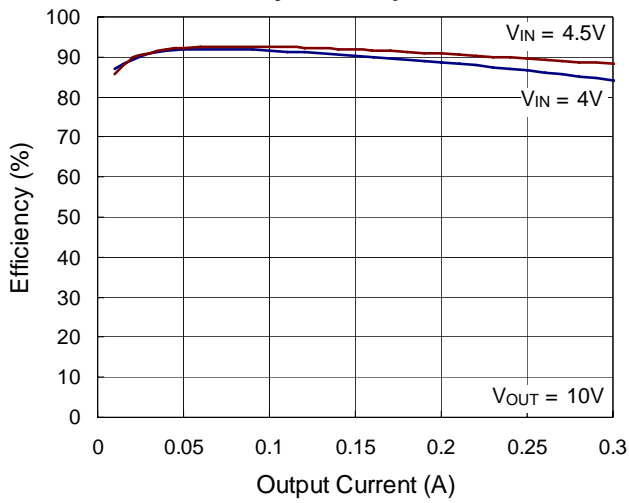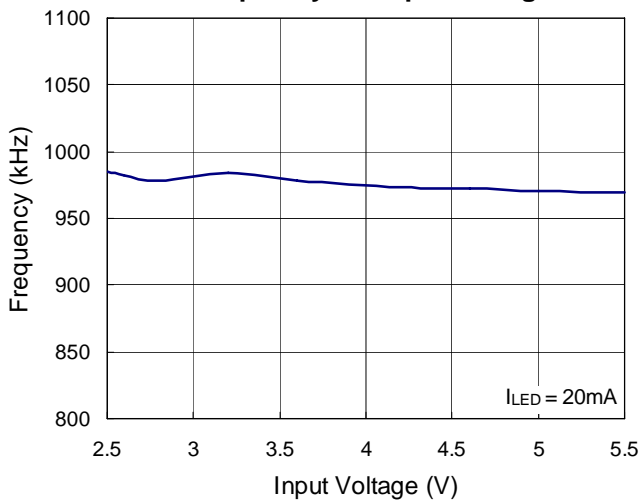

Efficiency vs. Input Voltage
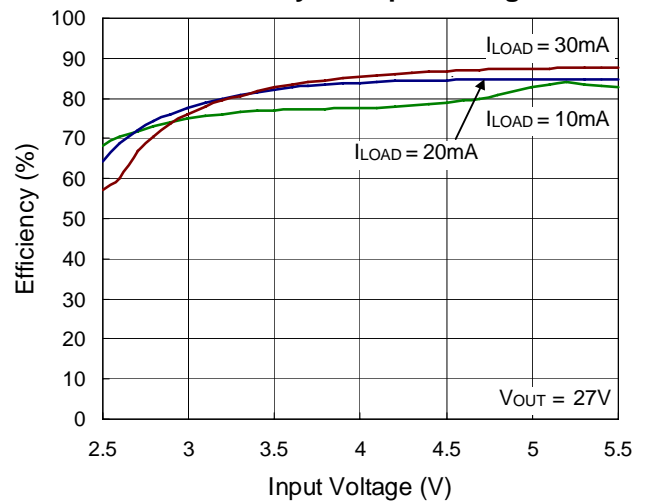
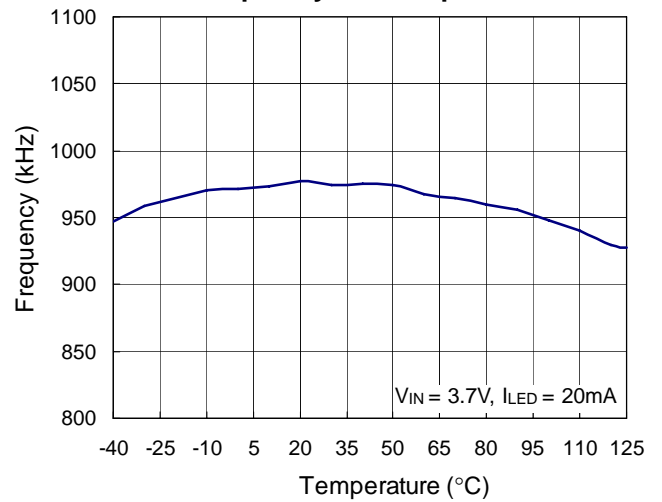**Output Voltage vs. Output Current**
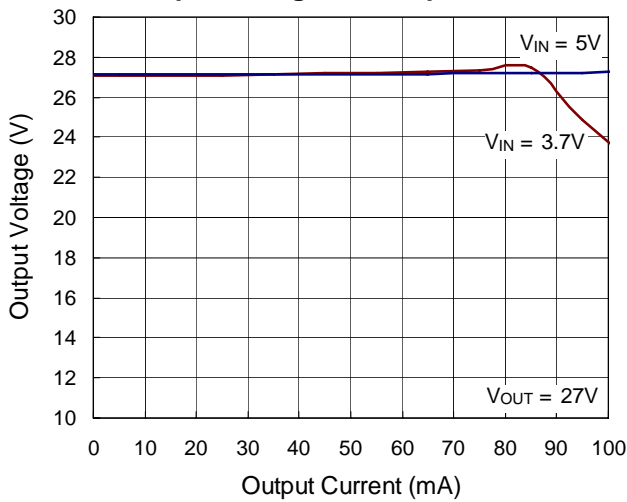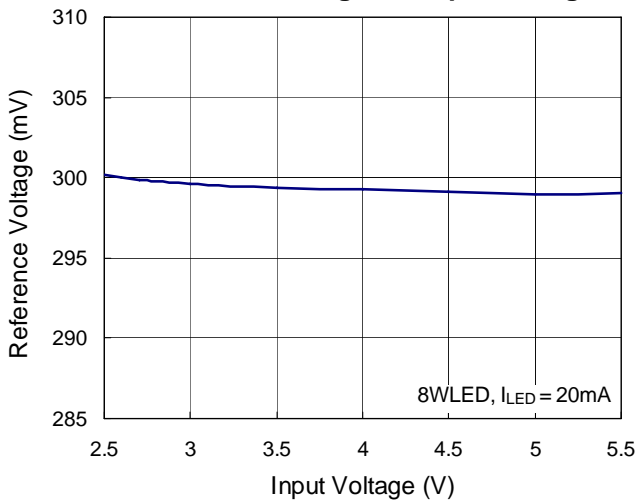

Quiescent Current vs. Input Voltage
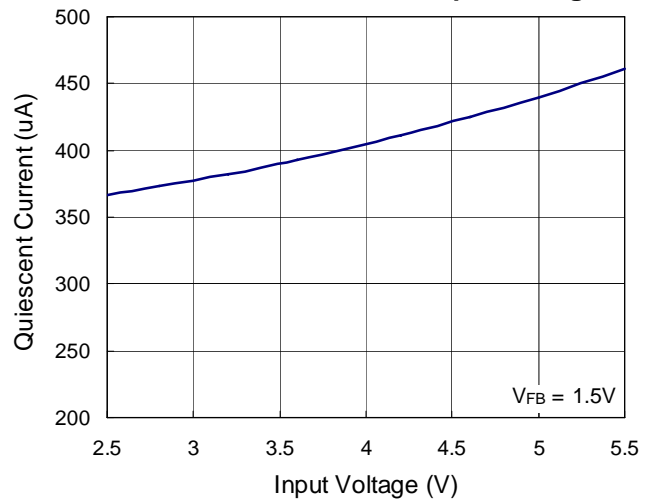
Frequency vs. Input Voltage

Frequency vs. Temperature

Reference Voltage vs. Input Voltage

8WLED, I_{LED} = 20mA

Reference Voltage vs. Temperature

V_{IN} = 3.7V

V_{IN} = 4.2V

I_{LED} = 20mA
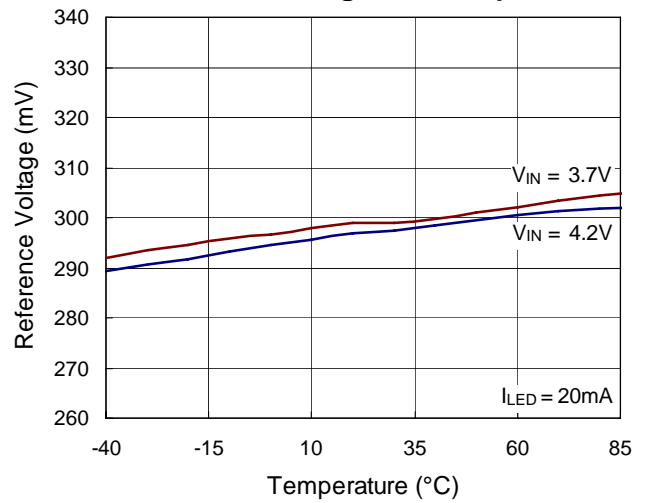
Reference Voltage vs. Output Current

V_{IN} = 3.7V
V_{IN} = 4.2V

V_{OUT} = 27V
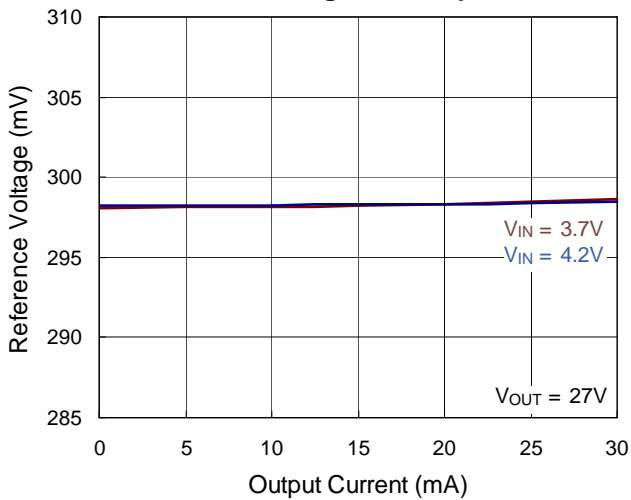
Enable Threshold vs. Input Voltage
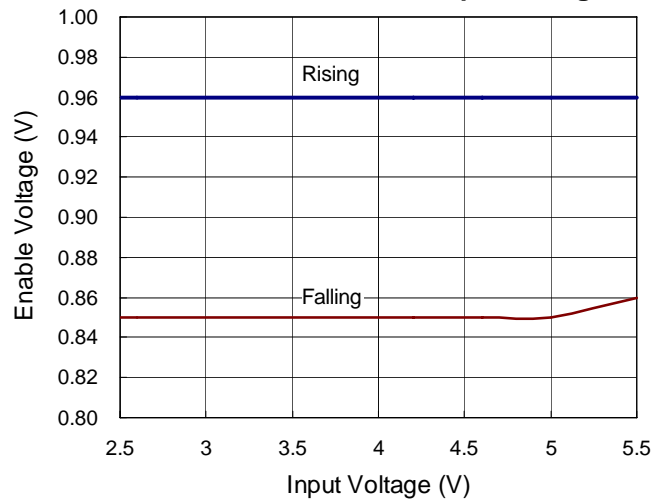
Rising

Falling

LED Current vs. Duty
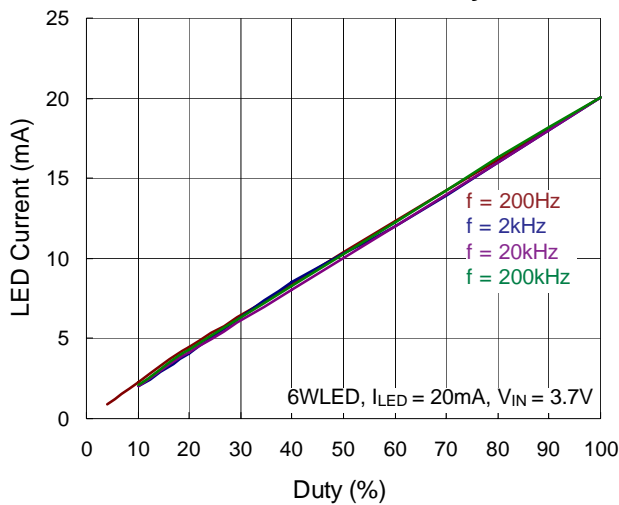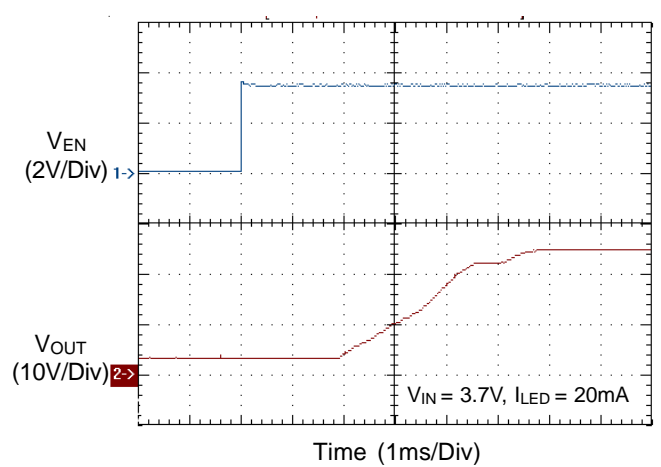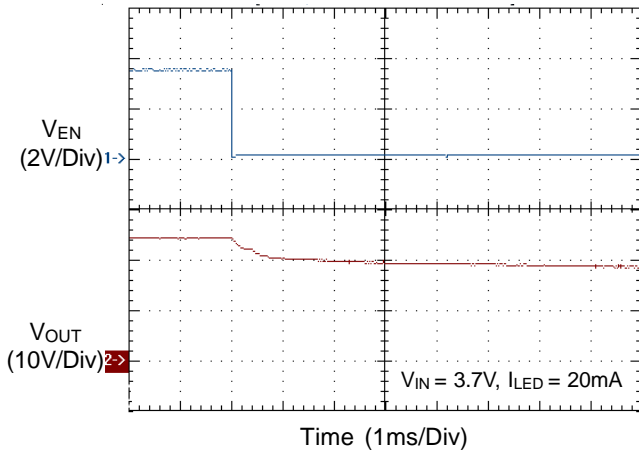
f = 200Hz
f = 2kHz
f = 20kHz
f = 200kHz

6WLED, I_{LED} = 20mA, V_{IN} = 3.7V

Power On from EN

V_{EN}
(2V/Div) 1->

V_{OUT}
(10V/Div) 2->

V_{IN} = 3.7V, I_{LED} = 20mA

Time (1ms/Div)

Power Off from EN

V_{EN} (2V/Div)
V_{OUT} (10V/Div)
V_{IN} = 3.7V, I_{LED} = 20mA

Time (1ms/Div)

Ripple Voltage

V_{IN} (20mV/Div)
V_{OUT} (20mV/Div)
V_{IN} = 3.7V, I_{LED} = 20mA

Time (500ns/Div)

PWM Dimming from EN

f = 200Hz
V_{EN} (2V/Div)
I_{LED} (10mA/Div)
V_{IN} = 3.7V, I_{LED} = 20mA, 6 LEDs

Time (1ms/Div)

PWM Dimming from EN

f = 20kHz
V_{EN} (2V/Div)
I_{LED} (10mA/Div)
V_{IN} = 3.7V, I_{LED} = 20mA, 6 LEDs

Time (10us/Div)

LED Open Before Enable

V_{IN} = 3.7V, I_{LED} = 20mA
V_{EN} (2V/Div)
V_{OUT} (10V/Div)
V_{LX} (10V/Div)

Time (5ms/Div)
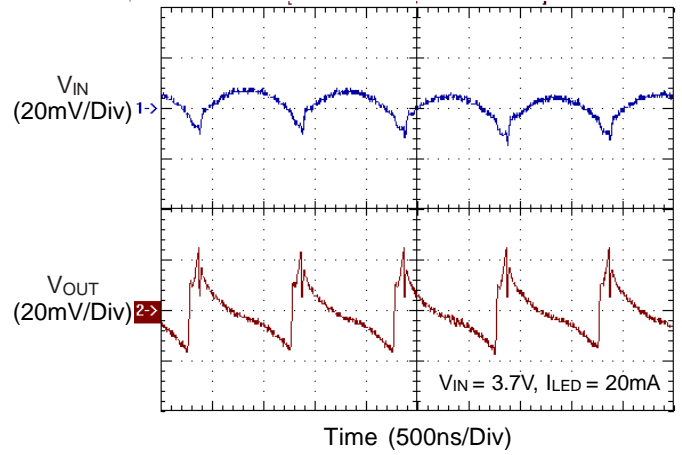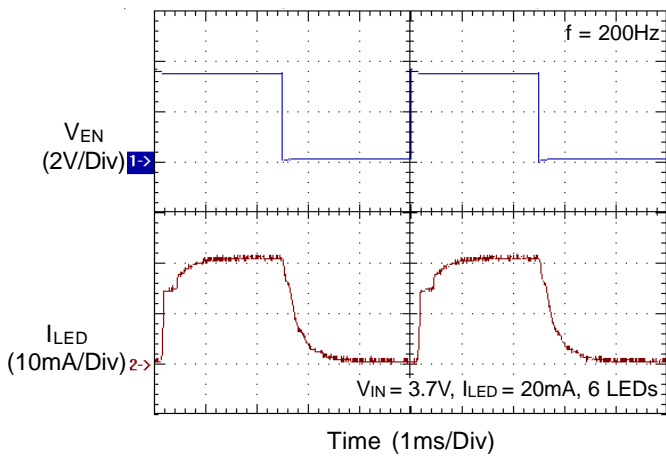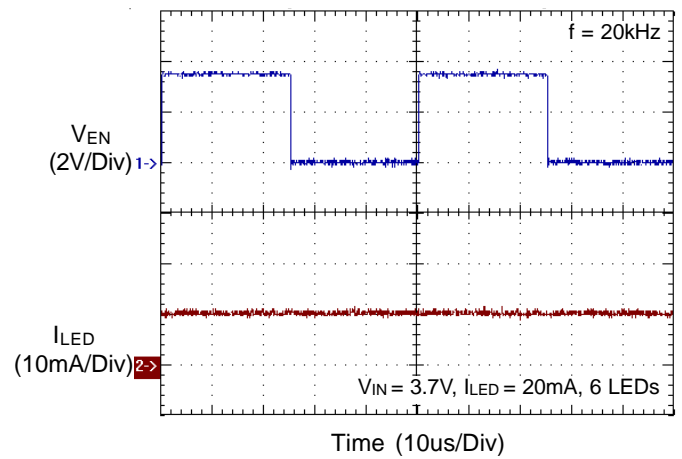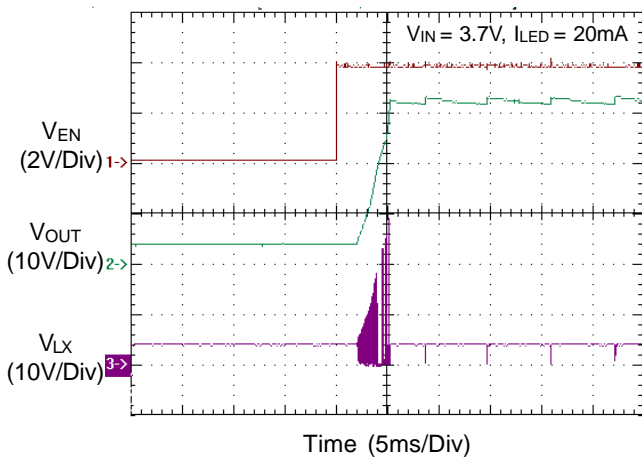
LED Open During Operation

V_{IN} = 3.7V, I_{LED} = 20mA
V_{EN} (2V/Div)
V_{OUT} (10V/Div)
V_{LX} (10V/Div)

Time (5ms/Div)
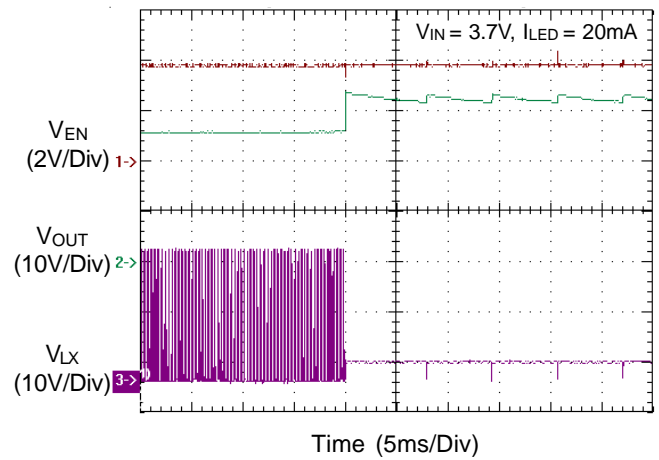
Applications Information

LED Current Setting

The loop of Boost structure will keep the FB pin voltage equal to the reference voltage V_{REF}. Therefore, when R_{SET} connects FB pin and GND, the current flows from V_{OUT} through LED and R_{SET} to GND will be decided by the current on R_{SET}, which is equal to following equation :

$$I_{LED} = \frac{V_{REF}}{R_{SET}}$$

Dimming Control

a. Using a PWM Signal to EN Pin

For the brightness dimming control of the RT4526, the IC provides typically 300mV feedback voltage when the EN pin is pulled constantly high. However, EN pin allows a PWM signal to reduce this regulation voltage by changing the PWM duty cycle to achieve LED brightness dimming control. The EN pin must be pulled to high for 1μs at least before the PWM dimming control. The relationship between the duty cycle and FB voltage can be calculated as following equation :

V_{FB} = Duty x 300mV

Where

Duty = duty cycle of the PWM signal

300mV = internal reference voltage

As shown in Figure 1, the duty cycle of the PWM signal is used to cut the internal 300mV reference voltage. An internal low pass filter is used to filter the pulse signal. And then the reference voltage can be made by connecting the output of the filter to the error amplifier for the FB pin voltage regulation.

However, the internal low pass filter 3db frequency is 500Hz. When the dimming frequency is lower then 500Hz, V_A is also a PWM signal and the LED current is controlled directly by this signal. When the frequency is higher than 500Hz, PWM is filtered by the internal low pass filter and the V_A approach a DC signal. And the LED current is a DC current which elimate the audio noise. Two figures of PWM Dimming from EN are shown in Typical Operating Characteristics section and the PWM dimming frequency is 200Hz and 20kHz respectively.

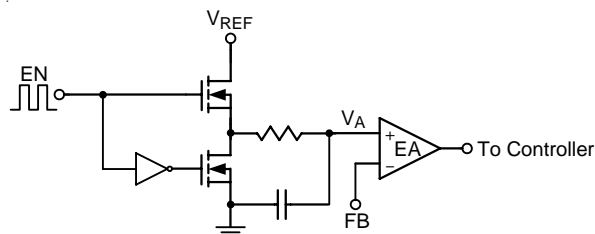For the RT4526, the minimum duty vs frequency is listed in following table.

Figure 1. Block Diagram of Programmable FB Voltage Using PWM Signal

	Minimum Duty
Dimming frequency < 500Hz	4%
Dimming frequency > 500Hz	10%

b. Using a DC Voltage

Using a variable DC voltage to adjust the brightness is a popular method in some applications. The dimming control using a DC voltage circuit is shown in Figure 2. As the DC voltage increases, the current flows through R3 increasingly and the voltage drop on R3 increase, i.e. the LED current decreases. For example, if the VDC range is from 0V to 2.8V and assume the RT4526 is selected which V_{REF} is equal to 0.3V, the selection of resistors in Figure 2 sets the LED current from 21mA to 0mA. The LED current can be calculated by the following equation :

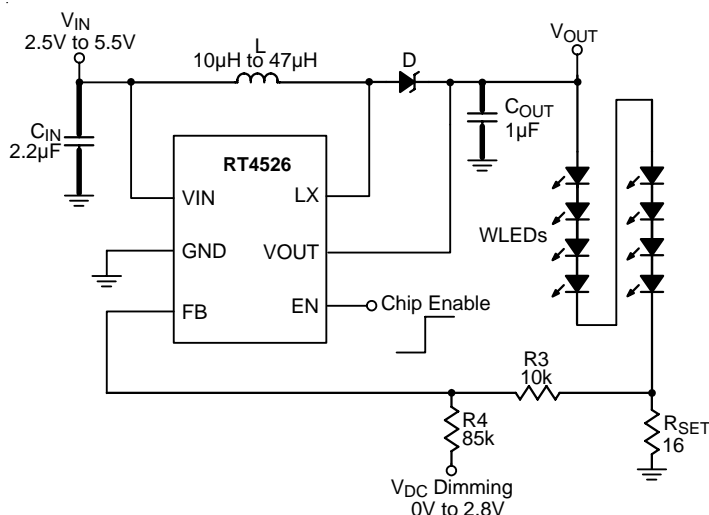$$I_{LED} = \frac{V_{REF} - \dfrac{R3 \times (V_{DC} - V_{REF})}{R4}}{R_{SET}}$$

Figure 2. Dimming Control Using a DC Voltage

c. Using a Filtered PWM signal

Another common application is using a filtered PWM signal as an adjustable DC voltage for LED dimming control. A filtered PWM signal acts as the DC voltage to regulate the output current. The recommended application circuit is shown as Figure 3. In this circuit, the output ripple depends on the frequency of PWM signal. For smaller output voltage ripple (<100mV), the recommended frequency of 2.8V PWM signal should be above 2kHz. To fix the frequency of PWM signal and change the duty cycle of PWM signal can get different output current. The LED current can be calculated by the following equation :

$$I_{LED} = \frac{V_{REF} - \dfrac{R3 \times (V_{PWM} \times Duty - V_{REF})}{R4 + R_{DC}}}{R_{SET}}$$
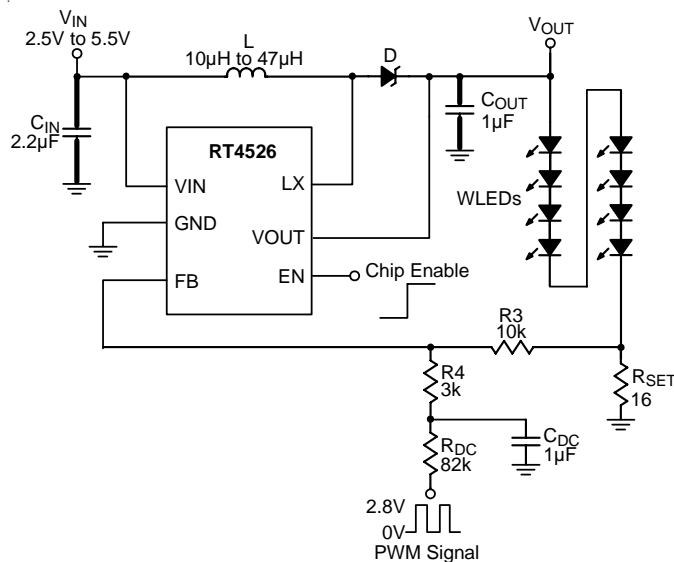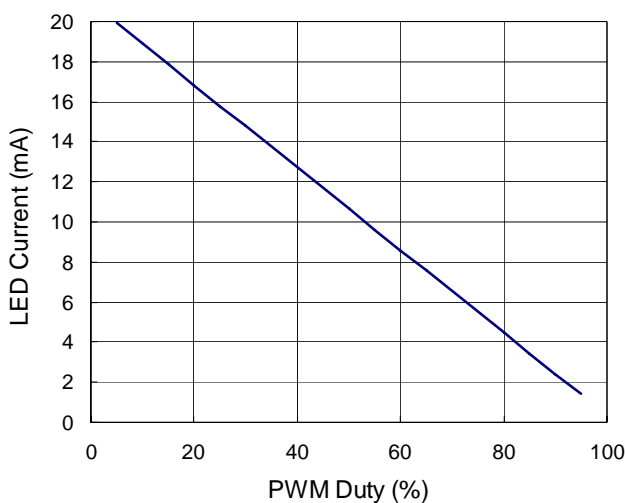
Figure 3. Dimming Control Using a Filtered PWM Signal

Figure 4. PWM Duty Cycle vs. LED Current

By the above equation and the application circuit shown in Figure 3, and assume the RT4526 is selected which V_{REF} is equal to 0.3V. Figure 4 shows the relationship between the LED current and PWM duty cycle. For example, when the PWM duty is equal to 60%, the LED current will be equal to 8.6mA. When the PWM duty is equal to 40%, the LED current will be equal to 12.7mA.

Constant Output Voltage Control

The output voltage of the R4526 can be adjusted by the divider circuit on the FB pin. Figure 5 shows the application circuit for the constant output voltage. The output voltage can be calculated by the following equations :

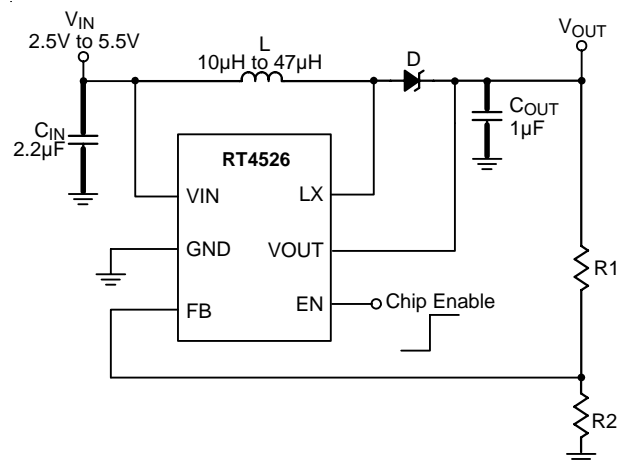$$V_{OUT} = V_{REF} \times \frac{R1 + R2}{R2} \; ; \; R2 > 10k$$
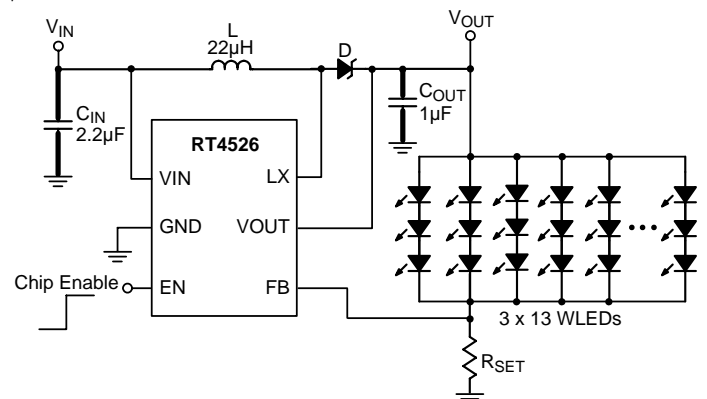
Figure 5. Constant Output Voltage Application

Figure 6. Application for Driving 3 x 13 WLEDs

Application for Driving 3 x 13 WLEDs

The RT4526 can drive different WLEDs topology. For example, the Figure 6 shows the 3 x 13 WLEDs and total current is equal to 260mA. The total WLEDs current can be set by the R_{SET} which is equal to following equation :

$$I_{Total} = \frac{V_{REF}}{R_{SET}}$$

Power Sequence

In order to assure the normal soft start function for suppressing the inrush current, the input voltage should be ready before EN pulls high.

Soft-Start

The function of soft-start is made for suppressing the inrush current to an acceptable value at the beginning of power-on. The RT4526 provides a built-in soft-start function by clamping the output voltage of error amplifier so that the duty cycle of the PWM will be increased gradually in the soft-start period.

Current Limiting

The current flow through inductor as charging period is detected by a current sensing circuit. As the value comes across the current limiting threshold, the N-MOSFET will be turned off so that the inductor will be forced to leave charging stage and enter discharging stage. Therefore, the inductor current will not increase over the current limiting threshold.

OVP/UVLO/OTP

The Over Voltage Protection is detected by a junction breakdown detecting circuit. Once V_{OUT} goes over the detecting voltage, LX pin stops switching and the power N-MOSFET will be turned off. Then, the V_{OUT} will be clamped to be near V_{OVP}. As the output voltage is higher than a specified value or input voltage is lower than a specified value, the chip will enter protection mode to prevent abnormal function. As the die temperature is higher than 160°C, the chip also will enter protection mode. The power MOSFET will be turned off during protection mode to prevent abnormal operation.

Inductor Selection

Small size and better efficiency are the major concerns for portable devices, such as the RT4526 used for mobile phone. The inductor value determines the operation frequency of the RT4526. Therefore, select the inductor value that ensures the operation frequency at the output maximum load current is not exceeded. The inductor value is calculated by the following formula :

$$L = \frac{V_{IN(MIN)} \times (V_{OUT} - V_{IN})}{I_P \times f_{OSC} \times V_{OUT}}$$

I_P = Inductor peak current

L = Selected inductor value

f_{OSC} = The operation frequency

$V_{IN(MIN)}$ = Tne minimum input voltagae

In the same inductor package size, smaller inductor value supplies higher output current. However, it lowers the efficiency. So, it is very important to select a suitable inductor value and the inductor saturation current must meet the maximum peak current requirement of the converter. The best way to calculate the maximum available load current under certain operating conditions is to estimate the expected converter efficiency at the maximum load current. The maximum load current can be estimated as follows :

$$I_{LOAD(MAX)} = \eta \frac{I_P^2 \times L \times f_{OSC}}{2 \times (V_{OUT} - V_{IN})}$$

I_P = Inductor peak current

L = Selected inductor value

f_{OSC} = The operation frequency

η = Expected converter efficiency

Finally, the inductor should have low core loss at operation frequency (1MHz) and low DCR for better efficiency. The recommended value of inductor for 6 WLEDs applications is from 10μH to 47μH.

Capacitor Selection

For good input and output voltage filtering, low ESR ceramic capacitors are recommended. The ceramic capacitors should be accepting the input and output voltage range. X5R and X7R types are suitable because of their wider

voltage and temperature ranges. For output voltage filtering, it is recommended to use large capacitor value to reduce the output ripple. However, it will increase the cost and required PCB area. The output voltage ripple can be calculated as :

$$\Delta V_{OUT} = \frac{I_{OUT}}{C_{OUT}} \times (\frac{1}{f_{OSC}} - \frac{I_P \times L}{V_{OUT} + V_d - V_{IN}}) + I_P \times ESR$$

I_P = Inductor peak current

L = Selected inductor value

f_{OSC} = The operation frequency

I_{OUT} = Nominal load current

V_d = Rectifier diode forward voltage (internal diode typically 0.7V)

C_{OUT} = Selected output capacitor

ESR = Output capacitor ESR value

A 2.2μF/6.3V ceramic input capacitor and 1μF/50V ceramic output capacitor is sufficient for driving 6 series WLEDs.

Thermal Considerations

For continuous operation, do not exceed absolute maximum operation junction temperature. The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surroundings airflow and temperature difference between junction to ambient. The maximum power dissipation can be calculated by following formula :

$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$

Where $T_{J(MAX)}$ is the maximum operation junction temperature, T_A is the ambient temperature and the θ_{JA} is the junction to ambient thermal resistance.

For the recommended operating conditions specification of RT4526, the maximum junction temperature of the die is 125°C. The junction to ambient thermal resistance θ_{JA} is layout dependent. The junction to ambient thermal resistance for TSOT-23-6 package is 255°C/W on the standard JEDEC 51-3 single layer thermal test board. The maximum power dissipation at $T_A = 25$°C can be calculated by following formula :

$P_{D(MAX)}$ = (125°C − 25°C) / (255°C/W) = 0.392W for TSOT-23-6 package

The maximum power dissipation depends on operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance θ_{JA}. For RT4526 packages, the Figure 7 of derating curves allows the designer to see the effect of rising ambient temperature on the maximum power
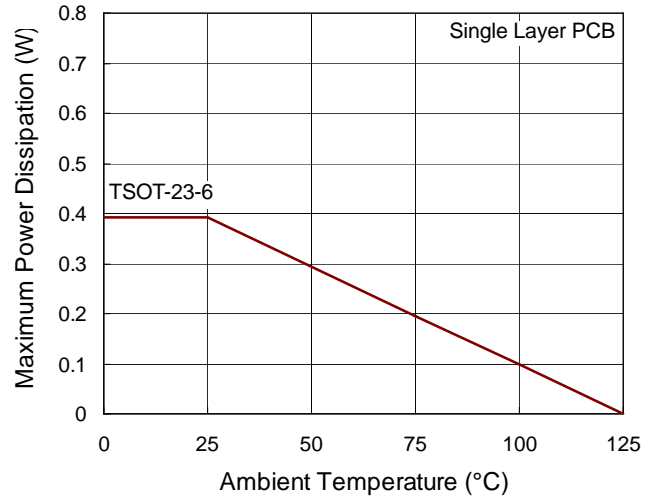

Figure 7. Derating Curves for RT4526 Packages

Layout Consideration

For best performance of the RT4526, the following guidelines must be strictly followed.

‣ Input and Output capacitors should be placed close to the IC and connected to ground plane to reduce noise coupling.

‣ The GND and Exposed Pad should be connected to a strong ground plane for heat sinking and noise protection.

‣ Keep the main current traces as short and wide as possible .

‣ LX node of DC/DC converter is with high frequency voltage swing. It should be kept at a small area.

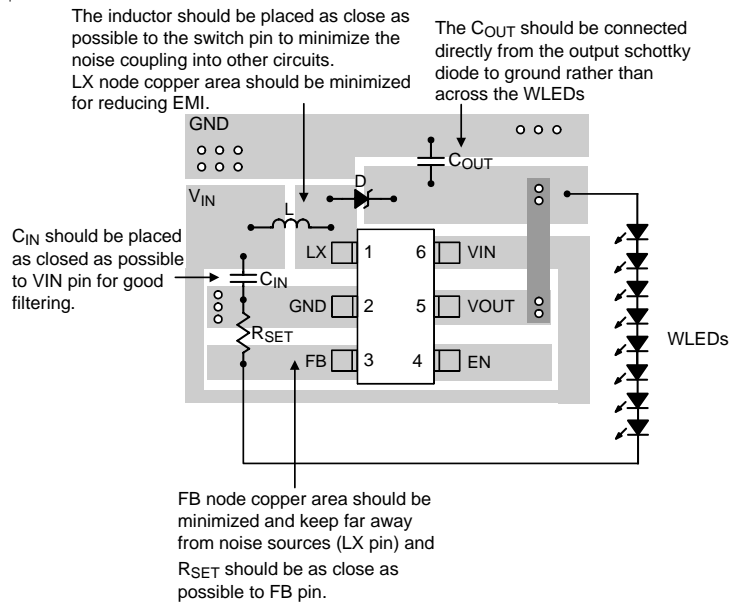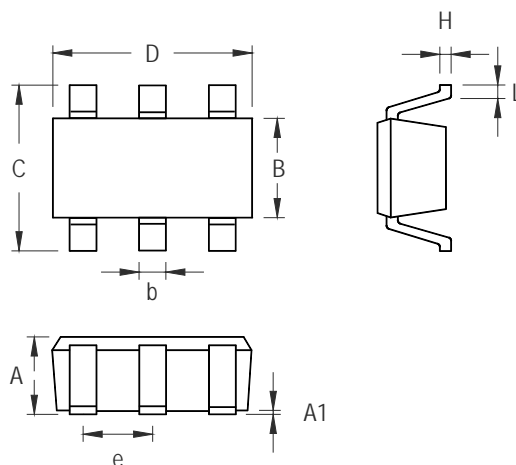‣ Place the feedback components as close as possible to the IC and keep them away from the noisy devices.

The inductor should be placed as close as possible to the switch pin to minimize the noise coupling into other circuits.
LX node copper area should be minimized for reducing EMI.

The C_{OUT} should be connected directly from the output schottky diode to ground rather than across the WLEDs

C_{IN} should be placed as closed as possible to VIN pin for good filtering.

FB node copper area should be minimized and keep far away from noise sources (LX pin) and R_{SET} should be as close as possible to FB pin.

Figure 8. PCB Layout Guide

Outline Dimension

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	1.000	0.028	0.039
A1	0.000	0.100	0.000	0.004
B	1.397	1.803	0.055	0.071
b	0.300	0.559	0.012	0.022
C	2.591	3.000	0.102	0.118
D	2.692	3.099	0.106	0.122
e	0.838	1.041	0.033	0.041
H	0.080	0.254	0.003	0.010
L	0.300	0.610	0.012	0.024

TSOT-23-6 Surface Mount Package